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## Deciphering the global onset of Oceanic Anoxic Event 2 (OAE2) in the mid-Cretaceous greenhouse world

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The mid-Cretaceous (~120 Ma to ~90 Ma) is a well-known greenhouse period in the Earth's history that was punctuated by multiple dramatic paleoceanographic changes known as oceanic anoxic events (OAEs). Among these OAEs, OAE2 occurred near the Cenomanian-Turonian boundary (CTB, ~93.9 Ma) and represents one of the most pronounced OAEs. OAE2 is widely believed to be triggered by submarine volcanism, primarily based on proxy records from the Northern Hemisphere in which a large osmium isotope excursion indicative of volcanism precedes the carbon isotope excursion (CIE) of OAE2. However, the timing and mechanism of the global initiation of OAE2 remain elusive in part due to the lack of detailed osmium-isotope proxy records across the OAE2 intervals in the Southern Hemisphere. Here we report a high-resolution initial osmium isotope ( $^{187}\text{Os}/^{188}\text{Os}_i$ ,  $\text{Os}_i$ ) and  $\delta^{13}\text{C}_{\text{org}}$  record from a highly expanded OAE2 interval in southern Tibet, China that was deposited in the northern margin of India Plate in eastern Tethys in the Southern Hemisphere. The  $\text{Os}_i$  record documents three distinct  $\text{Os}_i$  shifts toward unradiogenic compositions with increasing amplitudes at ~95.1 Ma, ~94.8 Ma, and ~94.5 Ma, respectively, indicating episodic, intensifying volcanism with the highest intensity episode at ~94.5 Ma. In addition, the large  $\text{Os}_i$  excursion at ~94.5 Ma is followed by an ~200 kyr  $\text{Os}_i$  minimum concomitant with a cooling interval as revealed by an overall broad minimum interval of the difference of the paired  $\delta^{13}\text{C}_{\text{carb}}$  and  $\delta^{13}\text{C}_{\text{org}}$ . This cooling interval is broadly synchronous with the Plenius Cold Event (PCE) recorded in the Northern Hemisphere. Furthermore, the large  $\text{Os}_i$  excursion paradoxically lags the onset of OAE2 by ~50 kyr at the Tibetan section. Comparison with and re-examination of the expanded OAE2 record of the Yezo Group (Japan) and those from the western interior seaway (WIS) in North America reveal the regional difference in the phasing relationship between the large  $\text{Os}_i$  excursions and the CIEs of OAE2. Intriguingly, the large  $\text{Os}_i$  excursions occurred during a near synchronous global transgression at ~94.5 Ma that led to increased connectivity of global oceans. Taken together, these results suggest that enhanced ocean connectivity was essential in helping trigger the global onset of OAE2 at ~94.5 Ma.